RESEARCH IN AGRICULTURAL ENGINEERING, 1922,

By R. W. Trullinger,*
Specialist in Rural Engineering, Office of Experiment Stations,
U. S. Department of Agriculture.

The purpose of this report is to draw attention to the more prominent features of agricultural engineering experimentation, investigation, and research completed, in progress, or in process of formulation during the year at the State agricultural colleges and experiment stations, certain other State and Federal institutions, and certain foreign agricultural and engineering institutions. Attention is also drawn in some cases to work which will be followed at the State experiment stations during the year 1923.

Considerable of the agricultural engineering investigational work being conducted at State colleges and experiment stations is apparently still in charge of departments other than that of agricultural engineering, thus making absolute accuracy and completeness in a report of this nature quite difficult to attain. Furthermore, it has been disclosed that much of the investigational work conducted by State institutions other than the experiment stations is frequently not made public at all. It is known that in some such cases highly important developmental work has been entered into through force of necessity to meet a demand for information, usually for teaching purposes.

During the year a representative of the Office of Experiment Stations visited seven State colleges and experiment stations for the special purpose of conferring with officials on the planning of agricultural engineering research. A significant feature of these visits was the evidently deep interest of administrative officials in the development of agricultural engineering along fundamental lines. All experiment station directors interviewed expressed a willingness to give carefully prepared projects in agricultural engineering embodying elements of research equal consideration with other agricultural projects in the allotment of research funds. The importance of thorough consideration and planning of a project before bringing it to the attention of a director is thus plainly evident.

Consultation with the agricultural engineering officials at these institutions revealed the existence of numerous unsolved agricultural engineering problems of a highly important and, in some cases, a very pressing nature. The intelligent planning and replanning of certain important projects at these institutions have already had the result that two institutions are preparing to place certain agricultural engineering work on a research basis, one institution has prevented the suspension of certain of its Federal research work, and three other institutions have obtained definite State fund support for research. Reports received from numerous other agricultural colleges and experiment stations indicate that many agricultural engineering departments and

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divisions are beginning to think along similar lines, and some have taken quite definite and effective steps to place the study of agricultural engineering problems on a research basis in the experiment stations. Everything considered, the outlook for the substantial development of agricultural engineering along fundamental lines is most bright and promising. This may be better appreciated by a careful consideration of some of the more important details of the work itself.

As usual the work in agricultural engineering completed, in progress, or planned during the year included the following general subjects: Farm machinery, farm buildings, drainage, irrigation, farm water supply and sewage disposal, land clearing, materials of construction, and miscellaneous.

FARM MACHINERY

A striking feature of the farm machinery program for the year has been the discontinuance, suspension, or "completion" of numerous indefinite blanket projects covering a multitude of details and obviously including practically no research features. Agricultural engineering departments are learning that experiment station directors and other officials charged with the administration of research funds are not particularly interested in supporting work of an indefinite nature on a very general subject. On the other hand, cases involving a clear and specific purpose and a well thought out line of approach and method of procedure are likely to receive attention.

This has been particularly true of tractor work. Last year it was noted that the Iowa, Indiana, Alabama, New York Cornell, California, and several other stations had expansive projects in operation covering the general subject of tractors. This year the tendency seems to be to deal with important specific phases of the subject in a systematic manner. The Alabama Station, for instance, has narrowed its tractor study down to a project on the relation of the physical factors of soil to impulsive traction. The object of this study is to determine the fundamental factors which influence wheel traction and to determine lines of maximum, minimum, and intermediate resistance in soil and lines of maximum, minimum, and intermediate impulsive stress from tractor wheels and lugs, with a view to making lines of maximum impulse coincident with lines of maximum resistance in soil as a basis for the development of the proper shape, size, location, and inclination of lug on a tractor wheel to give maximum impulsive traction on the worst agricultural soils in the State of Alabama. The statement of the object of this study alone gives evidence of an exhaustive and painstaking preliminary analysis and study of the subject. The preliminary results already indicate certain new and striking features, among which is the fact that a tractor has a certain minimum permissible slip for highest tractive efficiency, or, in other words, that the highest tractive efficiency is not always obtained by the least slip.

The Indiana station is apparently still engaged in studies to determine the slip of various types of tractor wheel equipment. No accurate information is available as to the research status of this project, but it is suspected that it so far consists merely of a set of comparative tests. It

is assumed, however, that the purpose is to determine the best methods available as a basis for a more fundamental study.

The California station has already published a preliminary report on its studies of air cleaners for tractor motors. It is understood that this work constitutes the preliminary elimination study of available types.

A project has been in progress at the Wisconsin station on the effect of kerosene as a fuel upon the lubrication of tractor motors. The results so far have shown that lubricating oil with an initial viscosity of 540 seconds at 100°F. deteriorated at the end of 15 hours running so that the viscosity had dropped to an average of 200 seconds. The greatest drop in viscosity occurred during the first 2.5 hours. This work is of special importance to users of kerosene-burning tractors, and opens up an important although not particularly unknown field of study.

In fact, there has been a considerable amount of study in private, State, and Federal institutions in this country and abroad on fuels for and lubrication of internal-combustion engines and tractor motors. Numbered among the foreign institutions are the British Ministry of Agriculture, Bureau of Science, Manila, certain French and German agricultural experiment stations, the Hawaiian Sugar Planters' Association, the agricultural departments of Australia and South Africa, and others. In this country several private institutions have conducted some most excellent research upon both fuels and lubrication.

The tendency in the fuel research has been to develop the use of alcohol fuel and to develop anti-knock materials to mix with hydrocarbon fuels. For instance, it has been found that owing to its low volatility, alcohol treated with ether obtained from alcohol by dehydration makes the best motor alcohol. The action of corrosive compounds formed by the combustion of such a mixture has been found to constitute a serious problem. Investigations so far have shown that the most suitable basic chemicals for neutralizing the corrosive acids produced are the amines either primary, secondary, or tertiary. Tractor tests with such fuels have shown that starting is easy and full power is developed. The fuel consumption in tests averaged 50 per cent more than when gasoline was used, however.

It has been found that about 1 gal. of absolute alcohol can be made from 2.2 gal. of molasses containing 57.7 per cent of sugar. In this connection the South Africal Department of Agriculture has been studying processes for the bacterial production of tractor motor fuels containing alcohol and acetone. It has been found that acetol, a fuel consisting of alcohol and acetylene gas, owes its properties largely to the fact that the addition of acetone to the alcohol increases the absorption of acetylene gas, thus increasing the calorific value of the mixture. Studies have also been conducted on the production of alcohol from wastes such as corn cobs, pineapple refuse, sweet potatoes, and other organic materials by fermentation with certain organisms such as Bacillus acetoethylicum capable of producing alcohol and acetone direct from starchy substances.

It may be well to state at this point that the Alabama station is considering a project on the refining of crude cane syrup. It is understood that this matter has been charged to the agricultural engineering division. The preliminary plan is apparently to take up a study of the refining process in cooperation with the chemistry department. As a means for paying the expense of refining, it is proposed to use the by-products thereof for the manufacture of alcohol motor fuel, the use of which in tractor motors may be developed in the mechanical laboratory.

Studies have been continued in the Belgian Congo on the development of palm oil as an internal-combustion engine fuel. The advantages of this fuel seems to be low carbonization, high percentage combustion, and low consumption of lubricating oil.

The Bureau of Chemistry of the U. S. Department of Agriculture has continued its studies of fuel gas made by carbonizing straw. It has been found that a ton of sun-dried wheat straw will yield approximately 10,000 cu. ft. of purified gas, having a calorific value of about 400 B. T. u. per cubic foot.

Studies conducted by the research department of one of the larger private institutions on detonation characteristics of some blended motor fuels and the chemical control of gaseous detonation in internal-combustion engines have yielded some especially interesting and valuable results. It has been found that detonation or knock in internal-combustion engines can be either suppressed or induced by the presence of very small amounts of certain materials in the combustible mixture. The compounds possessing this property are chiefly derivatives of about 15 elements. Oxygen and the halogens in the elemental form exert a marked effect upon combustion. Iodine is an anti-knock material, while the other elements induce detonation to different degrees. A great many nitrogen compounds are effective anti-knock materials, probably the best of which are the aromatic amines. Certain compounds of selenium, tellurium, tin, and lead are remarkably effective for the suppression of knock, while some compounds of arsenic, antimony, and phosphorus have a marked but lesser anti-knock effect. When benzol was blended with paraffin fuels in percentages larger than 20, its anti-knock effect increased rapidly as its concentration increased. Toluene on the basis of volume was more effective than benzene for eliminating detonation, and zylene was in turn still more effective than toluene. The addition of 1 per cent of xylidine to a fuel giving incipient detonation made it possible to raise the engine compression about 10 lbs. without increasing the detonation. On the volume basis, alcohol was considerably more effective than benzol for the suppression of detonation when blended with a paraffin fuel. The detonating tendency of a fuel composed of two ingredients was found to be greater than the average of the values representing the detonating tendencies of the two components taken separately. A practical test of these results in Germany showed that a fuel consisting of 53 per cent benzol, 34 per cent alcohol, and 13 per cent tetralin gave almost as high a thermal efficiency as pure benzol, and the use of higher compression ratios was possible.

The Massachusetts Institute of Technology has developed approximate methods for determining the total sensible heat contents of internal-combustion

engine gasoline and kerosene and their mixtures with air at temperatures up to 500° C. (932°F.), making it possible to calculate with sufficient accuracy for all practical purposes the resultant temperature of an air fuel mixture when the temperatures of the two constituents before mixing are known.

The South African Department of Agriculture and the French Academy of Agriculture have conducted some interesting studies on the use in tractor motors of low-grade gas produced by the combustion of charcoal. The latter institution found that the cost of operating a 35 h.p., 4 cylinder tractor with gasoline on plowing was from six to seven times greater than when gas was used. The gas produced about 25 per cent less power per unit than gasoline and caused the use of more lubricating oil. Valves, valve seats, and spark plugs were left in better condition by the gas than by gasoline, however.

The Massachusetts Institute of Technology, the Texas station, the British Ministry of Agriculture, the National Physical Laboratory of Great Britain, and the French Academy of Science have been especially active during the past year in studies of lubricating oils and of lubrication of internal-combustion engines.

The work at the Texas station seems to have been undergoing preliminary analysis and planning for a year and a half. Apparently it has narrowed down to a study of the lubrication of engine bearings, the purpose being to establish the physical and chemical properties of lubricating oils necessary to meet the conditions of proper lubrication of crank shaft and connecting rod bearings under different severe conditions of operation. This work will probably involve cooperation with the department of chemistry, and will thus not be limited to lubricating oils available. It is apparently intended to find out first what a lubricating oil should accomplish under certain conditions and then proceed to develop the oil itself. It is understood that the definite and substantial support of the agricultural experiment station is assured for this work. Striking features of this project are, first, that the agricultural engineering department is taking plenty of time in the preliminary analysis and study of the subject in order that the project may be placed in the best of shape for intelligent prosecution, and second, the intention seems to be to center all efforts on this one project and bring it to satisfactory completion before starting something else. This might be a questionable procedure under other circumstances, but if one considers the magnitude and far-reaching fundamental importance of the project the wisdom of careful and painstaking preparation and of concentration of effort during actual prosecution is apparent.

As a preliminary to a similar project, studies have been conducted in France on frictional losses in internal-combustion motors. It has been possible so far to establish a definite mathematical relation between friction losses and mean pressure for certain experimental motors, and an effort is being made to broaden this to include definite classes and groups of motors. The Massachusetts Institute of Technology has conducted fundamental studies on the mechanism of lubrication and the measurement of the property of oiliness. The National Physical Laboratory of Great Britain has been working on

the improvement of the lubricating properties of mineral oils by the addition of fatty acids. A significant general result of these studies is that a very considerable reduction in the static coefficient of friction of mineral oil was effected by the addition of as little as 0.1 per cent of fatty acid whether as pure oleic acid, acid rape oil, or rape oil fatty acids. The rape oil fatty acids were the most effective.

Valuable studies of far-reaching importance have also been conducted on crank-case oil dilution problems by certain private institutions. These have led to the development of automatic crank-case oil regeneration systems and methods which are opening up new and interesting fields of study.

According to inspection reports the tractor testing work at the Nebraska station, under the State law, is still in progress. Of course, such work is not exactly research, but apparently it is opening up some very interesting avenues of study and drawing forcible attention to numerous unsolved problems for future study. There have been numerous other tractor projects apparently in operation at some of the colleges and stations, but these have obviously been so general in nature as to not warrant any special mention.

As usual the so-called economic surveys of tractors have been given considerable attention. In addition to the institutions mentioned in last year's report, the Montana, West Virginia, and New Hampshire stations have become interested in tractor economics. The U. S. Department of Agriculture also continued its studies along this line but in a much more comprehensive manner than would be possible or feasible for a State institution.

While the Research Committee does not condemn these economic studies, it has felt that their value has quite definite limitations. With the large number of tractors on the market it is no longer an intelligent procedure to accept them at their face value. In fact, there seems to be a tendency on the part of some of the agricultural engineering departments to inject a little more engineering into these economic studies. It takes more time and money to do this and results are not so quickly obtained, but they are much more valuable when available. For instance, there is now a tendency at certain State institutions to include in the customary questionnaire to farmers and tractor users questions as to exactly why a particular tractor failed or used too much fuel, water, or lubricating oil. And the tendency seems to be growing to stick to these questions until they are satisfactorily answered. This has resulted in the opening up of problems for study and experimentation on tractors which might otherwise remain unknown and unsolved.

Experimental and developmental work on problems of such origin has been in progress at the Georgia State College of Agriculture, for instance, The reclamation of worn valves, the regrinding of cylinders, and the development of new designs of pistons and cylinders to make regrinding unnecessary have been important subjects of such investigations.

It is believed to be becoming more strongly evident that an intelligent admixture of engineering precision in economic surveys of tractors as

well as in surveys of other machines will tend not only to reveal successes and failures, but also the exact causes therefor, thereby pointing the way to further improvement and development and preventing the unnecessary repetition of mistakes.

Very few general tractor trials were conducted during the year, and this type of engineering pastime seems to be losing in popularity. In fact, the British Ministry of Agriculture in reporting on the Shrawardine tractor trials concludes that the conditions under which such trials are conducted do not give sufficient time or opportunity for adequate testing. It is considered that trials, including sustained tests which will extend to laboratory work on materials and soils and which will be continued as far as the resultant crop, are more to be desired. On the other hand, the Egyptian Ministry of Agriculture conducted two different sets of tractor trials which resulted in the striking conclusion that on Egyptian soils wheel tractors are more efficient than caterpillar types.

Almost every agricultural college and experiment station has recently evinced some interest in the improvement of farm machinery other than tractors. This general interest has in a number of cases narrowed down to a study of certain definite factors or features. The draft of farm implements especially has been engaging the attention of a number of institutions and is a striking instance of the growth of interest in investigational work. Two years ago this subject was being studied by only one or two institutions. Now at least six of our experiment stations are actively engaged in prosecuting projects of study on one or more phases of the draft of farm implements and the factors affecting it. These include the New York Cornell, California, Montana, Iowa, Nebraska, and Missouri stations, and it is believed that other colleges and stations are doing similar work of which there is no record available.

The New York Cornell station has been developing a traction dynamometer for the testing of heavy draft implements and perfecting integrating devices for studying the records. The California station has studied the power requirements of plowing, with special reference to the economic limits of animal and mechanical power. The Iowa station has apparently completed its well-known study of the influence of speed upon the draft of plows and is engaged in a study of the factors affecting the draft of farm wagons. A comparative study of the work and merits of round and cutaway blade causes from 10 to 20 per cent heavier draft and penetrates more deeply than the round blade.

The Missouri station has had a rather voluminous project in operation on the draft of various farm implements, but more especially it seems of tillage machines. The influence on draft of different soil types and of soil treatments has also been studied. Recent results have shown that, while the draft of plows is materially decreased by disking first, the total amount of work done is greater than to plow without disking in spite of the greater draft. The draft per foot of width of a single disk penetrating an average depth of 1.25 in. in silt loam corn soil was 81 lbs. and when penetrating 3 in. in silt loam soil which had been fall plowed it was 108 lbs. The station is also interested in the draft of wagons on different kinds of roads.

The plow draft investigations at the Nebraska station constitute probably the best planned and equipped project on the subject on record. This project is apparently an outgrowth of years of preliminary study and planning which have been narrowed down to a searching investigation of certain specific fundamental factors. Recent results of a large number of plowing tests made under varying depths and speeds varied widely in the case of speed draft tests, but were fairly consistent for depth draft tests. The increase in draft due to increase in depth from 5 to 10 in. was approximately 27 per cent of the draft at 5 in. Tests to determine the draft of a disk harrow for different angles of the disk sections and the effect of weight on the draft showed that the increase in draft due to fully angling the sections was about 175 per cent of the draft at no angle. A weight of 180 lbs. increased the draft 60 per cent. Attention should also be drawn to the studies of resistances to the translation of motor vehicles being conducted by the Iowa Engineering Experiment Station. These have already indicated the importance of rolling resistance and of low-grade surfaces.

The Iowa station also has a project on the standardization of farm machinery, a cooperative project with the agronomy division on experimental methods for machinery investigations, a project on grain grading and cleaning machinery, and a cooperative project with the soils division on limestone and fertilizer spreaders. It is understood that the last named project has been completed. In this project tests of commercial limestone spreaders and a study of the various methods of handling limestone showed that the desirable features of a limestone spreader are that it should be able to handle wet or dry stone, it should pass stones without injury to the machine, and it should spread uniformly and be calibrated with reasonable accuracy. The studies showed that the revolving finger type of distributor gives the most accurate calibration and uniform distribution, and that the most desirable type of spreader would be in the form of a trailer behind a loaded wagon, the material being shoveled directly from the wagon to the spreader. While this type did not spread as uniformly as some others, it handled larger stones without breakage. None of the commercial machines tested fully met the above requirements, so the station proceeded to develop a machine which worked very satisfactorily. It is desired to draw special attention to the manner in which this project was planned and conducted. It began with a study of what a limestone spreader should do, passed through the stages of testing available types, and ended by the development of a satisfactory machine.

A similar study has been conducted at the Michigan station where a lime spreader was developed to be attached to the rear end of the wagon box and operated by a rocker arm dropping from peg to peg on a disk attached to and turning with the rear wheels of the wagon. The rocker arm moves a board under the hopper which serves as an agitator. The jarring action of the rocker arm upon the agitator and box serve to feed down the lime. This machine was successfully tested with pulverized limestone both dry and damp.

The Alabama station has a project on fertilizer distributing equipment, which it is understood is still in the process of preliminary study, to determine the necessary and desirable features of such equipment.

The Wisconsin station has been studying the efficiency of various types of silage cutters and developing a marsh plow for breaking new land, both on State funds. The Arkansas station has been engaged in a study in cooperation with the agronomy and farm management departments on machinery necessary to space cotton with acid-delinted seed to save cost of chopping. That station is also engaged in a survey of farm machinery conditions in Arkansas. The research status of these projects is a matter of question.

The New York Cornell station has been studying the thermal efficiency and mechanical reliability of the Hvid engine. This project should be of interest since it is known that certain tractor and farm engine manufacturers are interested in the development of this type of motor. The Michigan station has two projects, one on the efficiency of farm machinery and the other on power machinery, the research status of which is not known.

The New York Geneva, Connecticut Storrs, Iowa, and South Dakota stations have projects on milking machines. It is understood that these projects are confined either to the dairy or bacteriology departments. It is believed that here are instances in which cooperation with the agricultural engineering departments might be profitable, especially where efforts are being made to improve the efficiency of milking machines. The New Zealand Department of Agriculture has found such a cooperative arrangement to be quite profitable, judging from the results of a recent study of the use of electric power for milking plants. Records from five plants for 12 consecutive months showed that the most effective application of electric power to milking machine work under New Zealand conditions consists of a small self-contained outfit, comprising an electric motor, vacuum pump, cream separator, small water supply pump, and a 10-gal. water cistern, with the necessary switch gear, all mounted on a compact hardwood base plate.

Among the more miscellaneous machinery investigations, the wearing tests of plowshares at the California station should be mentioned. It has been found so far that the least wear is shown by chilled cast-iron shares, slightly more by soft center steel, and considerably more by manganese steel. While these tests are perhaps more or less preliminary in nature, yet the results obtained are quite interesting and open up what may be a field of research of far-reaching importance in plow development and design. The writer has always advocated a more thorough study of the possibilities of cast-iron and semi-steel for cultivating machinery, and the results of this study so far appear to be quite significant in that connection.

Studies at the Experimental Institute of Mechanical Agriculture of Argentina on windmills have resulted in the development of an improved type adapted for the operation of a vertical double-acting plunger pump.

Studies by the British Ministry of Agriculture on the economics of harvesting oats with a horse-drawn binder, a tractor-drawn binder, a tractor and two binders, and a tractor-drawn combination binder and shocker showed that mechanical binding effected a saving of 75 per cent in hand labor over hand binding. The combined operations of binding and shocking gave results considerably superior to the two binders plus hand shocking. This project has resulted in the development of a fairly satisfactory mechanical shocker.

The British Ministry of Agriculture has also been engaged in studies of potato diggers. The preliminary analysis and study showed that a successful machine should bring the potatoes well to the surface, leave them exposed and undamaged, and the draft of the machine must be comparatively light. The rotary or spinner type gave the best results, and its general principles are considered to be sound, but further research is necessary into the problems of speed, angle of time, projecting load, and the resultant effect on the potatoes as well as the ease of digging. The advantages of a low speed gear and an angle of tine of 45° in a rotary machine were reflected in the smaller proportion of damaged potatoes and the small number left in the ground.

A final piece of machinery research of interest to agricultural engineers which should be mentioned is that conducted by the U. S. Bureau of Standards on the power lost as heat in automobile tires when operated under different conditions of axle load, inflation pressure, speed, and tractive effort. The loss increased directly with an increase in speed or axle load and increased quite rapidly with a decrease in air pressure below the standard. Tractive effort has a comparatively small effect upon power loss. Fabric tires as a class showed considerably greater losses than cord tires.

FARM BUILDINGS:

There is a record of only 17 projects of study on farm buildings and structures in force or completed during the year at the State experiment stations. During the previous two years almost every agricultural college and experiment station had some sort of a farm structures project, but it seems that many of these have been so general and indefinite as to reach the limits of their usefulness and have become inactive from lack of support. As in the case of farm machinery projects, experiment station directors and other officials administering research and investigational funds are no longer much interested in supporting farm building and structures projects unless they relate to the development of some specific and important feature, and the line of approach and method of procedure are well worked out.

The Iowa State college and experiment station, with its many and varied farm building projects, has apparently been one of those to realize this and to act accordingly. Out of 9 or 10 general projects several have been discontinued and others have been completed. In their place are found a few more definite and better planned projects tending to nail down certain fundamental facts regarding a few of the more important features of farm structures, most of which are probably more or less well known.

The Michigan station has been studying the framing of barns and the ventilation of potato storage houses. The latter study, which was discussed with the writer over two years ago, has indicated in its preliminary features that successful potato storage under Michigan conditions depends upon the maintenance of a dry atmosphere and a temperature as low as from 33 to 38°F. To provide movement of air through as well as around potato piles it has been found that the bins should not be wider than 8 ft. nor deeper than 10 ft., and they should be kept some distance from the outside walls. Both the King and Rutherford systems have been successfully used.

It is understood that the Missouri station has continued its silo and silage investigations which include wall construction and deterioration, capacities, etc. This work undoubtedly includes some research features. It is to be noted that it has been in operation since 1913. A similar study is in progress at the Guam Station.

A great majority of the stations have continued their work on poultry houses. Prominent among these are the Kansas, Kentucky, Pennsylvania, Montana, Washington, and New Jersey stations. It is noted that most of this work has been in charge of poultry husbandry departments exclusively. While valuable data has undoubtedly been secured, it frequently exists in no very usable shape, and an intelligent application of it to variable conditions is often quite difficult. It is thought that the practice of conducting such studies in cooperation with the agricultural engineers should be encouraged in some cases. Poultry houses, especially for large-scale operations, call for intelligent design and construction involving a knowledge of materials, ventilation, and structural design which anyone can not possibly possess unless especially trained therein. The amount of study being conducted on the subject indicates that it has never been thoroughly solved. An intelligent cooperation with the agricultural engineering divisions may be a step of considerable importance in placing such work on a more firm and permanent basis.

The workers on the subject of building ventilation now have an ally in the U. S. Public Health Service. That institution has apparently been studying the efficiency of various kinds of ventilating ducts, if not directly at least through some of its collaborators. Uniformity of air distribution through ducts operating on different principles was especially studied.

The work of the U. S. Department of Agriculture on farm building ventilation is so well known as to need no description. It is felt that this work is developing into a piece of the highest type of research.

The Ohio College of Agriculture, has engaged in a study of braced rafter barn framing, with special reference to its adaptation to dairy barns. The Nebraska station has apparently completed its several years study of hog houses, and the British Ministry of Agriculture is engaged in a study of the design and construction of cow sheds to meet agricultural conditions in England.

It is understood that the Kentucky station has been and is now engaged in the preliminary analysis and planning of a project on tobacco-curing barns. Recent developments indicate that this project may involve cooperation between the agricultural engineers, the tobacco specialists, and plant pathologists. It is desired to draw special attention to the intelligent and searching manner in which it is proposed to approach the study of this subject. The purpose, as explained to the writer, is to find out first exactly what will be required of barns to properly cure different grades of tobacco, and then to proceed with development on that basis.

The Agricultural Society of Austria has been engaged in studies of floors for farm buildings. These have indicated in their preliminary phases that clinkers, clinker concrete, and sand cement floors are among the better materials for stock barns.

The South African Department of Agriculture has continued its studies of pise-de-terre farm buildings, and one of our private institutions has made a valuable contribution on the preservation of decaying wood roofs. This study showed that decay in roofs is usually greatest in planks and beams at bearings, because, due to the additional insulating properties of the supporting members, the locus of moisture dips. Tops of roof rafters and girders rot first, and decay is usually more active near ventilators and cold conductor pipes. The treatment consists in removing the water supply from the fungus causing decay by preventing condensation through insulation of the outer roof surface.

DRAINAGE:

The study of soil drainage at the State experiment stations has apparently been undergoing somewhat of a change for the better during the past year. It was stated in last year's report that considerable of the work in progress on drainage was not of a very high order of research. It is noted that the tendency to overhaul drainage projects with a view to injecting some more obviously research features into the work seems to be growing.

For instance, the North Carolina station has a cooperative project on the efficiency of underdrains which has included studies of run-off, the relation of run-off to rainfall, and the lowering of ground water level. While these studies have yielded considerable data and have considered different soil types, it has been realized that they have dealt largely with the manipulation of engineering hydraulic principles without sufficient reference to the soil itself. The purpose, as related to the writer, is to replan some of this work with a view to studying the influence of the physical and chemical properties of the soil and of different soil treatments and crops on underground run-off. The realization of the importance of such a procedure was brought about when certain tenacious clay soils were encountered, in which it was found that the application of ordinary drainage measures was unsaccessful. The importance of such a modification of customary procedure has also been recognized at the Georgia State College of Agriculture, and at the Alabama, Texas, Kentucky, and Virginia stations. It is also believed that this procedure is finding some considerable favor with the U. S. Department of Agriculture, since that institution seems to be gradually confining its drainage activities to the more strictly research features of the subject.

In connection with the study of the influence of the physical and chemical properties of soil on underdrainage, attention may well be drawn to the fact that certain German agricultural experiment stations have developed some rather definite hydraulic principles for German soils. Some of the preliminary studies of the relative permeabilities of soils as influenced by their content of fine and of coarse particles have shown that permeability increases as the content of coarser particles increases. Rather definite relations have been developed between permeability and clay content, calcium carbonate content, relative speed of sedimentation, so-called specific soil surface, specific weight, and other physical factors.

The Minnesota station has a project on the correlation of land and crop values with cost of drainage operating under the division of agricultural engineering. This subject seems to be gaining considerably in importance. It is understood that the Virginia station is planning a similar project for next year, but along much more comprehensive lines. The purpose, as related to the writer, is to effect a cooperative arrangement between the agricultural engineering, soils, field crops, and farm economics divisions to determine the economics status of drainage systems which have already been constructed in Virginia.

The Minnesota station is also engaged in studies of drainage and water control on peat lands and of the relative efficiencies of different depths and spacing of tile drainage lines. The Wisconsin station has been studying the settlement of peat after drainage.

The Oregon station has three projects of a general nature on the drainage of alkali and tide lands, and a rather definite project on the influence of clover, lime, and manure on the drainage of white lands. The Michigan, Montana, Mississippi, New Mexico, and California stations have similar drainage projects apparently of a general nature.

With reference to surface run-off, attention should be drawn to a study which the U. S. Weather Bureau has in progress to determine the influence of forests and vegetation on run-off. Also the Bureau of Public Roads of the U. S. Department of Agriculture has recently studied flow through cleared and uncleared flood-ways, which showed a difference in discharge capacity between cleared and uncleared channels of 62.5 per cent.

A review of the soils projects at the different experiment stations indicates that there are in operation at least 19 projects at as many stations on the relation of soil moisture and soil moisture movement to the physical and chemical properties of soils. The agricultural subject of soils and the engineering subject of drainage are obviously quite closely related. It would seem, therefore, that cases might frequently occur in which cooperation between the soils and agricultural engineering departments would be profitable in establishing fundamental hydraulic principles governing the underdrainage of soils.

IRRIGATION:

Irrigation is an old and well organized subject, and the investigational work therein has been extensive. Practically every State experiment station in the irrigated West has supported its quota of research projects in irrigation during the year. There is a record of at least 40 active projects in 12 States. It is true that some of these are too indefinite or general in plan to lay claim to a research status. The majority, however, are planned along research lines, and it is difficult to determine which are the more important.

These studies have covered almost all phases of irrigation. One of the newer features of the work is the development of pump irrigation. This has been studied at the Arizona, Utah, Montana, and Nebraska stations, and further work along this line is being planned at the New Mexico station. Duty of water has been studied at the Utah, Nebraska, California, Nevada, Oregon, and Montana stations. The Montana and Colorado stations are engaged in seepage studies, and the Colorado and Arizona stations are studying evaporation. The Colorado station has been especially active in studying the measurement of water, particularly with the Venturi flume and current meter. Similar work has been conducted by the Egyptian Ministry of Public Works and the U. S. Department of Agriculture. The Oregon station has studied methods of irrigation water distribution. In this study the strip border method was considered with reference to head, kind of soil, and width and length of border. Similar studies have been in progress in New Zealand, and it is understood that the California station has such a project under consideration. The Utah Station has engaged in studies of the composition of irrigation waters, and the Arizona, New Mexico, and Utah stations have been interested in studies of ground water.

Practically all of the stations dealing with irrigation have studied alkali soils and their reclamation by various treatments. The Nevada, Utah, and California stations and the Department of Agriculture of Canada have been especially active in this respect. The Utah station has conducted studies on the capacities of soils for irrigation water. A summary of data from a number of large irrigation projects has been gathered by the U. S. Reclamation Service, indicating that ordinarily 50 per cent of the water diverted for irrigation purposes becomes a source of return flow. The U. S. Reclamation Service has also reported studies on coefficients of discharge for suppressed submerged orifices, rating curves for canal head gates, metal flumes, concrete canal linings, and methods for the cleaning of canals.

The U. S. Department of Agriculture has been engaged in almost every phase of irrigation study and appears to be the leader in this work. It is to be noted that a large part of the State station work has been done in cooperation with the Federal Department.

About the only recommendation that can be made regarding the conduct of irrigation research is that the importance of considering the physical and chemical properties of the soil, the crops grown, and the soil treatments be not lost sight of. An instance of the importance of considering these factors occurred recently at one of the State stations where, through the cooperation of the soils and Plant pathology departments, discrepancies and nonuniformity in the results of deep percolation and duty of water studies were discovered and eliminated, thus preserving the accuracy of the results.

FARM WATER SUPPLY AND SEWAGE DISPOSAL:

Numerous well meant attempts have been made during the year to secure so-called practical information on the subject of farm sewage disposal for presentation to farmers. Some of these attempts are more or less successful, but undoubtedly they are more frequently the result of luck than of an exercise of fundamental knowledge.

The volume of practical information on this subject which is issued from some sources is most astounding, in view of the fact that institutions like the Rockefeller Institute of Medical Research, the New Jersey, Montana, Illinois, New York Cornell and other experiment stations, and the U. S. Public Health Service are investing funds in attempts to get at the fundamental principles of the subject. One needs only to summarize the existing fundamental information on the subject to realize that the greater part of our present so-called practical knowledge is based for the most part on guess work, mechanical skill, and the results of a few poorly planned experiments of very limited applicability, Much of the available information is not new at all and is obviously of quite limited fundamental importance.

In spite of the general lack of support of the subject, a few institutions have sifted the available knowledge of the subject down to the little bit that is of fundamental importance, and with this as a basis are beginning some actual research planned to bring out the scientific and engineering facts of the matter.

The Illinois station is planning a project to bring out the relation between septic tank dimensions and the chemical and biological changes taking place therein. It is proposed to conduct this work in cooperation with the State water survey and with such other divisions of the experiment station as have an interest in any part of the matter. It is understood that the system of grouping of conditions to be met is to be used as a basis which was proposed in a report appearing in the 1917 proceedings of the American Society of Agricultural Engineers. The New Jersey station has continued its study of the biology of sewage disposal and the Montana station is apparently still engaged in an effort to find out what a septic tank and an Imhoff tank are all about. The Michigan station has had a project in operation on the relation of the design of sewage disposal systems to successful operation. While this project sounds rather general, it is understood to embody some specific research features.

The New York Cornell station has two projects which should be mentioned, one on the relation of septic tank design to the accumulation of sludge and scum and the discharge of suspended solids in the effluent and another on the effectiveness of various dosing methods in subsurface absorption tile receiving the effluent from small domestic tanks. The Missouri and Minnesota stations also have sewage disposal projects in operation.

The Kansas State Agricultural College is understood to be planning a farm sewage disposal project. While no information is available as to the present status of the project, it is known that some considerable planning of a preliminary nature has been in progress, leading to a study which will require from five to ten years for completion.

The Rockefeller Institute of Medical Research has been engaged in a most exhaustive study of soil pollution and the relation of the various types of privies to the spread of intestinal infections. Some of the results so far obtained have occasioned considerable comment and controversy, but it is hard to disprove them with our present lack of fundamental information. For instance, it was found that both typhoid and dysentery bacilli died in from one to five days in septic tanks, but the typhoid bacilli survived from 10 to 15 days in

solid feces, and the dysentery bacilli not longer than five days. The paratyphoid bacilli were the most resistant members of the group. These are supposed to be encouraging statements, but when one considers the variable conditions of flow under which many of the so-called simple practical septic tanks, consisting of a square shallow box, operate there is very little protection in them, especially when retention periods are shortened by increased flow and final disposal is inadequate or non-existent.

The conclusion is drawn that in moderately compact clay, sand clay, or sandy soil free from cracks, the possibility of pollution of ground water is negligible, provided the ground water level is more than 10 ft. from the polluted area. It is to be noted that this conclusion is based on a very limited set of conditions only, and that alarming reservations are made for many other conditions. One of the most important features of this work is that it is drawing attention to numerous important points requiring further study.

The Ontario Agricultural College is engaged in an interesting study of the problems of freezing in septic tanks and absorption tile systems. The preliminary results show that the temperature in septic tanks is constantly higher than that of the surrounding air, and that fluctuations in temperature cover a much smaller range. This is true to an even greater extent in the tile. With a minimum outside temperature of --6°F. the minimum temperature in the tile was 34°, in the digestion chamber 44°, and in the flushing chamber 34°.

The Wisconsin State Board of Health has completed an 8-year study of sewage disposal systems for farm and rural homes and schools. These studies indicate that the cesspool is in general an obsolete and unsatisfactory method of sewage disposal. While it is considered that a septic tank is necessary to lessen the offensiveness of the sewage and place it in better physical condition for final treatment, it has been invariably found that septic tank effluent is just as dangerous to health as the raw sewage. The Idaho station on the other hand has reported studies on farm septic tanks from which the deduction is made that the materials driven into a septic tank are changed to simple harmless materials. They are said to enter the tank as a dirty, greasy mixture and leave it in a simple and sanitary form. It is further stated that the effluent may be run into an open field because it contains only completely decomposed substances and is not insanitary. This surprising statement is somewhat opposed to that made above by the Wisconsin State Board of Health and statements made by several other institutions. It is suspected that it is due in part at least to the fact that the soils in parts of Idaho are very porous and highly absorptive, making any final treatment of septic tank effluent unnecessary in many cases. The details of this work have not been made known to the Research Committee or the Office of Experiment Stations.

The Department of Health of New Jersey has made a study of Imhoff tanks for industrial and institutional sewage disposal which would indicate that the installation of this type of apparatus has been more or less promiscuous.

Studies in Great Britain on the adsorptive power of sand filters have shown that a sand filter freshly prepared is capable of absorbing fairly large amounts of ammonia and dissolved organic substances, and that this action

takes place rapidly. Sand that has ceased to absorb dissolved substances must be thoroughly washed before it again becomes active.

Several sets of interesting experiments have recently been conducted in parts of Germany on the use of sewage and sewage sludge for irrigation and fertilization and on disposal in fish ponds.

The Department of Agriculture and Technical Instruction of Ireland has been engaged in studies on the purification of creamery sewage by means of septic tanks and activated sludge treatment. These have so far indicated the advantage of a combination of these two treatments.

The Kentucky State College of Agriculture has recently reported a study of farm sewage disposal systems which indicated the importance of final treatment of septic tank effluent for the different farm conditions encountered in Kentucky. It is also understood that the institution is studying small water supply systems. The Kansas State Agricultural College is also interested in that subject, with special reference to soft water cisterns and filters. The New York State College of Agriculture has gone into the subject of water supply for farms probably as thoroughly as any other institution, and has been paying special attention to plumbing.

The North Carolina college and station have recently evinced considerable interest in knowing more about hydraulic rams. It is understood that rams have been installed under almost every conceivable condition, and it has been found that the old rule-of-thumb friction formulas do not always hold. In addition, curious losses of head have been observed under certain conditions which can not be explained on the basis of known hydraulic principles. An analysis of the subject has indicated that the present formulas, theories, and frictional coefficients are apparently not based on any very searching studies of hydraulic rams, but are known hydraulic principles for the most part which have been arbitrarily applied to hydraulic rams. While no special provision has been made for this work, it is understood to be planned eventually to make a thorough analysis and study of the subject to establish once and for all the engineering and hydraulic principles for this important apparatus.

LAND CLEARING:

The subject of land clearing, while not new, has undergone a process of very gradual but steady development. The Wisconsin, Minnesota, and Oregon stations apparently have continued their comprehensive studies of land clearing methods, and the Idaho station has been also engaged in such a study, although on not so extensive a scale perhaps.

The Alabama station studied ways and means of clearing stump land in Alabama, and developed some very effective methods, all of which cost considerable money, however. A study was then entered into on a relatively small scale to find out if the expense of clearing could be met by the sale of oils, tar, etc., obtained from the stumps by destructive distillation. The preliminary results indicated that this is quite a profitable procedure, at least on the small scale followed, and it is understood that a study is now being planned in cooperation with the chemical division to develope this process on a larger and

more practical scale which will include if necessary the refining of the pine stump products as a further source of profit. A highly commendable feature of this work is that it is planned to develop a process which will pay for itself and in many cases yield a profit. It should prove especially attractive for groups of the poorer class of farmer. It is thought that all institutions dealing with land clearing could well consider these features in view of the expense of clearing.

MATERIALS OF CONSTRUCTION:

Materials of construction as a subject in agricultural engineering has grown steadily in importance. While a great deal of the work done during the year has been of a comparative nature, yet most of it has served to give permanent results. A great deal of the work with lumber and with wood preservatives has been done by forestry or chemical departments. This has been true at the Ohio, Minnesota, New York Cornell, and Iowa stations on studies of the preservative treatment of fence posts. The Minnesota station has a project under the divisions of agronomy and farm management on the comparative value of fence posts of local origin when treated and used for long periods.

The Iowa station has a project on roofing materials, one on fence posts and concrete panel fences and one on cellular concrete construction for farm structures, all operating under the agricultural engineering section. The roofing studies have so far indicated that a protective layer of mica, sand, or crushed stone has a beneficial influence upon durability.

The Alabama station has a project on the preservation of wood and roofing, and the Pennsylvania station has been studying the preservation of shingles. These have shown that creosoted pitch and loblolly pine shingles have given as good results as red wood or red cedar shingles in a 13-year test. The Montana and Missouri stations and the American Wood Preservers' Association have been studying the preservative treatment of fence posts and structural timber with various chemicals. It has been found that zinc chlorid when used as a preservative decreases the strength of timbers subjected to relatively high temperatures. The University of Missouri is interested in a project on concrete fence posts.

The Montana and Wyoming stations have continued their studies on the effect of alkali upon Portland cement and the U. S. Department of Agriculture also has conducted some studies of this subject. These last have shown that the concrete highest in quality as indicated by strength and absorption best withstood the deleterious action of magnesium sulphate.

Both the Wisconsin and Minnesota stations are investigating the durability of concrete drain tile, especially in peat soils. The Minnesota studies have shown that cement tile may be used without risk in high-lime peat soils that are free of iron sulphid but are subject to attack and possibly to disintegration in low-lime peats. The cooperative study of concrete drain tile in alkali soils being conducted by the U. S. Department of Agriculture, the U. S. Bureau of Standards, and the U. S. Reclamation Service is still in progress and has recently yielded some interesting results. The U. S. Department of Agriculture has recently studied the stresses in concrete drain tile under

load in a trench. The analytical results indicate that the safe load per linear foot on such tile is greater than that allowed by the specifications of the American Society of Testing Materials. The department has also studied the coefficient of roughness in corrugated iron pipes on different grades.

The North Dakota Agricultural College has recently reported the results of its latest paint tests made in connection with the State paint regulatory work. The American Society for Testing Materials has also reported studies in stress-strain measurements of paint and oil films to determine changes and distortions therein and their causes. Studies by private parties on the relative values of paints and primers for the protection of wood against moisture have shown that paints and primers of the ordinary commercial brands are not effective as moisture proofing agents even when three coats are applied. The need for research on this subject is indicated. It is understood that the studies on the fungi injurious to paint have been continued at the New Jersey station.

The Colorado station has been studying the coefficient of heat transmission in commercial wall boards. In this connection it is well to note that the Department of Science and Industrial Research of Great Britain has been studying the thermal conductivity of insulating materials commonly used in cold storage work. So-called cellular expanded rubber consisting of rubber expanded by gas into a highly cellular form and having a high insulating value has been developed in this work.

Studies have also been in progress at Columbia University on concrete brick masonry which should be of interest to agricultural engineers. These have so far indicated that to produce masonry of the same strength, the strength requirements of individual brick would be considerably lower in the case of wet mixed concrete brick than for clay brick.

MISCELLANEOUS:

As usual, there are a few miscellaneous features of agricultural engineering being studied which are worthy of mention. The Alabama, Illinois, and Missouri stations and the Georgia State College of Agriculture have projects on soil erosion. It is understood that all these projects include studies on water penetration, run-off, and so-called washability of soils in relation to erosion and promise to yield some interesting results. The Iowa station has a project on the harvesting and storage of ice and the Minnesota and Virginia stations on hydroelectric farm plants. The Virginia project is now in process of preliminary planning and is considered to be a very important matter in that State. The University of Missouri is interested in farm lighting plants.

The University of Illinois is continuing its warm air furnace research, and has reported tests of humidity conditions in a residence heated by a warm-air furnace using recirculated air.

The Canadian Council of Science and Industrial Research has been studying fuel-saving possibilities in househeating and a well-known Federal war bureau has made available the results of study on the burning of kerosene in househeating boilers.

It may also be well to mention the studies at the University of Nebraska on the heat value of corn. These showed the relative heat value of corn and coal, indicating that with coal at $10 per ton the price of corn on the cob must be less than 20 cts. per bushel of 70 lbs. and of shelled corn less than 16 cts. per bushel of 56 lbs. to make it more economical to burn corn than to purchase coal. This comparison does not include any allowance for the cost of handling either fuel.

While tillage and tillage methods are subjects normally related to the work of agronomists, yet their intimate relation to the development of tillage machinery justifies the inclusion of some such works as miscellaneous matters of interest to agricultural engineers. The Oregon, South Dakota, North Dakota, Illinois, Texas, Minnesota, Utah, Arkansas, South Caroline, Wisconsin, Ohio, and North Carolina stations have projects on some phase of tillage or tillage methods. In nearly every case these projects are conducted by the soils or agronomy department and in no case by the agricultural engineering department. These projects cover such important factors as depth of plowing, differential tillage, weed eradication with different machines, subsoiling, packing, disking versus plowing, time of tillage, relation of tillage to moisture and plant nutrients, seed bed preparation, etc. It would seem that cooperation with the agricultural engineers on questions of tillage might frequently be a profitable procedure.

CONCLUSION:

The growth of the research spirit has been so marked during the year that it would not be practical at this time to draw conclusions as to the most important lines of future endeavor. Suffice to say that in almost every case where a sincere attempt has been made to get at the fundamentals of a question, numerous unsuspected and unsolved problems have been uncovered. It can be safely concluded that only the surface has yet been scratched, and that the future stability and permanence of agricultural engineering as a profession can be assured only by unceasing and painstaking effort to solve these problems in the order of their importance. The progress made during the year in this respect is indeed encouraging.